RARE EARTHS

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The principal economic sources of rare earths are the minerals bastnasite, monazite, and loparite and the lateritic ion-adsorption clays (table 2). The rare earths are a relatively abundant group of 17 elements composed of scandium, yttrium, and the lanthanides. The elements range in crustal abundance from cerium, the 25th most abundant element of the 78 common elements in the Earth's crust at 60 parts per million, to thulium and lutetium, the least abundant rare-earth elements at about 0.5 part per million. In rock-forming minerals, the rare earths typically occur in compounds as trivalent cations in carbonates, oxides, phosphates, and silicates.

Scandium, atomic number 21, is the lightest rare-earth element. It is the 31st most abundant element in the Earth's crust with an average crustal abundance of 22 parts per million. Scandium is a soft, lightweight, silvery-white metal, similar in appearance and weight to aluminum. It is represented by the chemical symbol Sc and has one naturally occurring isotope. Although its occurrence in crustal rocks is greater than lead, mercury, and the precious metals, scandium rarely occurs in concentrated quantities because it does not selectively combine with the common ore-forming anions.

Yttrium, atomic number 39, is chemically similar to the lanthanides and often occurs in the same minerals as a result of its similar ionic radius. It is represented by the chemical symbol Y and has one naturally occurring isotope. Yttrium's average concentration in the Earth's crust is 33 parts per million and is the second most abundant rare earth in the Earth's crust. Yttrium is a bright silvery metal that is soft and malleable, similar in density to titanium.

The lanthanides comprise a group of 15 elements with atomic numbers 57 through 71 and includes the following: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). Cerium, the most abundant of the group at 60 parts per million, is more abundant than copper at 50 parts per million, followed next in decreasing crustal abundance by yttrium at 33 parts per million, lanthanum at 30 parts per million, and neodymium at 28 parts per million. Thulium and lutetium, the least abundant of the lanthanides at 0.5 part per million, occur in the Earth's crust in higher concentrations than thallium, antimony, cadmium, and bismuth.

The rare earths were discovered in 1787 by Swedish Army Lieutenant Karl Axel Arrhenius when he collected the black mineral ytterbite (later renamed gadolinite) from a feldspar and quartz mine near the village of Ytterby, Sweden (Weeks and Leicester, 1968, p. 667). Because they have similar chemical structures, the rare-earth elements proved difficult to separate. It was not until 1794 that the first element, an impure yttrium oxide, was isolated from ytterbite by Finnish chemist Johann Gadolin (Weeks and Leicester, 1968, p. 671).

The elemental forms of rare earths are iron gray to silvery lustrous metals that are typically soft, malleable, and ductile and usually reactive, especially at elevated temperatures or when finely divided. Melting points range from 798º C for cerium to 1,663º C for lutetium. The rare earths' unique properties are used in a wide variety of applications.

In 1998, apparent consumption was estimated to have decreased as domestic mine production and imports of individual rare-earth compounds decreased substantially amid large increases for cerium compounds and mixed rare-earth compounds (table 1). Domestic production of bastnasite concentrates continued in 1998. Beginning in March 1998, refinery production at the Mountain Pass, CA, site of Molycorp, Inc., was suspended reportedly because of low rare-earth prices on world markets and unresolved regulatory and permitting requirements for a wastewater system (Unocal, 1998, p. 12).

Demand decreased for rare earths used in petroleum fluid cracking catalysts and in rare-earth phosphors for television, X-ray intensifying, and fluorescent and incandescent lighting. Yttrium was used primarily in lamp and cathode-ray tube phosphors, structural ceramics, and oxygen sensors.

The domestic use of scandium increased in 1998, but overall consumption remained small. Commercial demand increased as recently developed applications entered the market. Most metal, alloys, and compounds were used in sporting goods equipment, metallurgical research, and analytical standards. Minor amounts were used in specialty lighting and semiconductors.

Legislation and Government Programs

Public Law 105-85, the National Defense Authorization Act for Fiscal Year 1998 (October 1, 1997, through September 30, 1998), was enacted on November 18, 1997. It did not change the previous authorization for the disposal of all stocks of rare earths in the National Defense Stockpile (NDS).

Production

Domestic mine production data for rare earths are developed by the U.S. Geological Survey (USGS) from a voluntary survey of U.S. operations, "Rare Earths." The one mine to which a survey form was sent did not respond.

In 1998, one mining operation in California accounted for all domestic mine production of rare earths. Molycorp, a wholly owned subsidiary of Unocal Corp., mined bastnasite, a rare-earth fluorocarbonate mineral, by open-pit methods at Mountain Pass, CA. Mine production was estimated to have decreased from the 1997 estimated level of 10,000 metric tons of rare-earth oxide (REO) in concentrates.

Refined lanthanides were processed by two companies in 1998. Molycorp ceased production of refined compounds from bastnasite at its separation plant at Mountain Pass as a result of a blocked wastewater pipe that underlies land administered by several Federal and State Government jurisdictions. Alternative wastewater disposal methods and water conservation plans were being considered.

Rhodia, Inc. (previously Rhône-Poulenc Basic Chemicals Company), a subsidiary of the French company Rhône-Poulenc S.A., produced rare-earth compounds from rare-earth intermediate compounds at its facility at Freeport, TX. Grace Davison, a division of W.R. Grace & Co., refined rare earths from rare-earth chlorides and other rare-earth compounds for petroleum fluid cracking catalysts at Chattanooga, TN.

Except for minor amounts of yttrium contained in domestically produced bastnasite concentrates, essentially all purified yttrium was derived from imported compounds.

Three scandium processors operated in 1998. High-purity products were available in various grades with scandium oxide produced up to 99.999% purity. Sausville Chemical Co. refined scandium at its refinery facilities to Knoxville, TN. The company expected to produce high-purity scandium compounds, including oxide, fluoride, nitrate, chloride, and acetate. Boulder Scientific Co. processed scandium at its Mead, CO, operations. It refined scandium primarily from imported oxides to produce high-purity scandium compounds, including diboride, carbide, chloride, fluoride, hydride, nitride, oxalate, and tungstate.

Scandium was also purified and processed from imported oxides at Aldrich-APL in Urbana, IL, to produce high-purity scandium compounds, including oxide, fluoride, and hydrous and anhydrous chloride. The company also produced high-purity scandium metal.

Principal domestic producers of neodymium-iron-boron magnet alloys were Magnequench International, Inc., Anderson, IN; Neomet Corp., Edinburg, PA; and Rhodia, Phoenix, AZ. Leading U.S. producers of rare-earth magnets were Magnequench, Hitachi Magnetics Corp., Edmore, MI; Crumax Magnetics, Inc., Elizabethtown, KY; and Ugimag Inc., Valparaiso, IN.

Consumption

Statistics on domestic rare-earth consumption were developed by surveying various processors and manufacturers, evaluating import-export data, and analyzing U.S. Government stockpile shipments. Domestic apparent consumption of rare earths decreased in 1998 compared with that of 1997. Domestic consumption of rare-earth metals and alloys increased in 1998. Consumption of mixed rare-earth compounds decreased as demand for mixed intermediates for petroleum fluid cracking catalysts weakened.

Based on information supplied by U.S. rare-earth refiners, selected consumers, and analysis of import data, the approximate distribution of rare earths by use was as follows: automotive catalytic converters, 35%; glass polishing and ceramics, 31%; metallurgical additives and alloys, 14%; petroleum refining catalysts, 10%; permanent magnets, 5%; fiber optics and rare-earth phosphors for lighting, televisions, computer monitors, radar, and X-ray intensifying film, 3%; and miscellaneous, 2%.

In 1998, yttrium consumption was estimated to be 516 tons, an increase from 292 tons in 1997. Yttrium compounds were imported from several sources in 1998. Yttrium compounds were imported from China, 64.5%; France, 18.4%; the United Kingdom, 7.5%; Japan, 4.5%; Belgium, 4.1%; and the Netherlands, 1.0%. Yttrium was used primarily in lamp and cathode-ray tube (CRT) phosphors, 68%; structural ceramics and abrasives, 13%; and oxygen sensors, lasers, electronics, superalloys, and miscellaneous, 19%.

Tariffs

U.S. tariff rates, specific to the rare earths, including scandium and yttrium, were unchanged from 1997 except for the lowering of the tariff for cerium compounds (U.S. International Trade Commission, 1998). Selected rare-earth tariff rates for countries with “Normal trade relations” (previously “Most favored nation”) and “Non-normal trade relations” (previously “Non-most favored nation”) status, respectively, were as follows: HS 2805.30.0000 rare-earth metals, including scandium and yttrium, whether intermixed or interalloyed, 5.0% ad valorem, 31.3% ad valorem; HS 2846.10.0000 cerium compounds, 5.8% ad valorem, 35% ad valorem; HS 2846.90.2010 mixtures of rare-earth oxides except cerium oxide, Free, 25% ad valorem; HS 2846.90.2050 mixtures of rare-earth chlorides, Free, 25% ad valorem; HS 2846.90.4000 yttrium-bearing materials and compounds containing by weight greater than 19% but less than 85% yttrium oxide equivalent, Free, 25% ad valorem; HS 2846.90.8000 individual rare-earth compounds, including oxides, nitrates, hydroxides, and chlorides (excludes cerium compounds, mixtures of REO, and mixtures of rare-earth chlorides) 3.7% ad valorem, 25% ad valorem; HS 3606.90.3000 ferrocerium and other pyrophoric alloys, 5.9% ad valorem, 56.7% ad valorem; HS 7202.99.5040 ferroalloys, other (including rare-earth silicide), 5.0% ad valorem, 25% ad valorem; and HS 7601.20.9090 aluminum alloys, other (including scandium-aluminum alloys), Free, 10.5% ad valorem.

Special rare-earth tariffs for Canada and Mexico were the result of Presidential Proclamation 6641, implementing the North American Free Trade Agreement, effective January 1, 1994. Under the agreement, tariff rates for most rare-earth products from Canada and Mexico were granted free status and those that were scheduled for staged reductions have achieved free status. Tariff rates for most other foreign countries were negotiated under the Generalized Agreement on Tariffs and Trade Uruguay Round of Multilateral Trade Negotiation.

Stocks

U.S. Government stocks of rare earths in the NDS classified as committed for sale/pending shipment were 385.93 tons (425.42 short tons) at yearend 1997. In 1998, all remaining stocks of rare earth in sodium sulfate held in the NDS were shipped during the first half of 1998. All stocks of rare earths in the NDS were previously sold; at yearend 1997, however, the NDS contained a total of 386 metric tons (425 short tons) of rare earths contained in sodium sulfate. All previously sold stocks were shipped from the NDS in 1998— 219 tons was shipped in January; 62 tons, in February; 67 tons, in March; 38 tons, in April; and the remaining 0.038 ton, in May (Defense Logistics Agency, 1998).

Prices

Rare-earth prices were mixed in 1998. Domestic prices for cerium oxide increased, and neodymium prices decreased slightly. Prices decreased slightly for dysprosium, erbium, gadolinium, holmium, and lutetium; most other oxide prices were unchanged from those of 1997. The following prices were estimated by the author based on the basis of trade data from various sources. All rare-earth prices remained nominal and subject to change without notice. Competitive pricing policies remained in effect with prices for most rare-earth products quoted on a daily basis. The average price of imported rare-earth chloride was $2.43 per kilogram in 1998, a decrease from $2.60 per kilogram in 1997. In 1998, imported rare-earth metal prices averaged $17.64 per kilogram, a decrease from $22.70 per kilogram in 1997. Mischmetal and specialty mischmetals comprised most rare-earth metal imports. (Mischmetal is a natural mixture of rare-earth metals typically produced by metallothermic reduction of a mixed rare-earth chloride.) The price range of mischmetal was $13.00 to $19.00 per kilogram at yearend 1998 (Elements— Rare Earths, Specialty Metals and Applied Technology, 1998). The average annual price for imported cerium compounds, excluding cerium chloride, decreased to $3.10 per kilogram from $6.92 per kilogram in 1997. The primary cerium compound imported was cerium carbonate.

The estimated market price for bastnasite concentrate was $3.91 per kilogram. The price of monazite concentrate, typically sold with a minimum 55% rare-earth oxide, including thorium oxide content, free-on-board (f.o.b.) as quoted in U.S. dollars and based on the previous year's U.S. import data, was unchanged at $400.00 per metric ton. In 1998, no monazite was imported into the United States. Prices for monazite remained depressed because several principal international rare-earth processors continued to process only thorium-free feed materials.

The nominal price for basic neodymium-iron-boron alloy, compiled by the author from data supplied by several U.S. producers, was $17.64 per kilogram ($8.00 per pound), f.o.b. shipping point, 1,000-pound minimum. Most alloy was sold with additions of cobalt (up to 15%, typically 4% to 6%) or dysprosium (up to 3%). The cost of the additions was based on pricing before shipping and alloying fees; with the average cobalt price decreasing to $47.25 per kilogram ($21.43 per pound) in 1998, the cost would be about $0.47 for each percent addition per kilogram ($0.21 for each percent addition per pound).

Rhodia quoted rare-earth prices, per kilogram, net 30 days, f.o.b. New Brunswick, NJ, or duty paid at point of entry, in effect at yearend 1998, as listed in table 3.

No published prices for scandium oxide in kilogram quantities were available. Yearend 1998 nominal prices for scandium oxide per kilogram were compiled by the author from information provided by several domestic suppliers and processors. Prices decreased slightly from those of the previous year for most grades and were listed as follows: 99% purity, $1,100; 99.9% purity, $2,300; 99.99% purity, $3,400; and 99.999% purity, $6,750.

Scandium metal prices for 1998 were unchanged from those in 1997 (Alfa Aesar, 1997-98)—99.99% REO purity, lump, sublimed dendritic, ampouled under argon, $172 per gram; 99.9% REO purity, less than 250-micron powder, ampouled under argon, $570 per 2 grams; and 99.9% purity, lump, sublimed dendritic lump, ampouled under argon, $262 per 2 grams; 99.9% REO purity, foil, 0.025 millimeter thick, ampouled under argon, 25 millimeters by 25 millimeters, $96.90 per item.

Scandium compound prices as listed by Aldrich Chemical Co. (1998) were as follows: scandium acetate hydrate 99.9% purity, $57.45 per gram; scandium chloride hydrate $99.99% purity, $62.00 per gram; scandium nitrate hydrate 99.9% purity, $59.30; and scandium sulfate pentahydrate 99.9% purity, $60.05 per gram. Prices for standard solutions for calibrating analytical equipment were $22.70 per 100 milliliters of scandium atomic absorption standard solution and $338.15 per 100 milliliters of scandium plasma standard solution.

Prices for kilogram quantities of scandium metal in ingot form have historically averaged about twice the cost of the oxide, and higher purity distilled scandium metal have averaged about five times the cost.

Foreign Trade

U.S. exports of rare earths decreased as imports increased in 1998. U.S. exports totaled 9,630 tons valued at $71 million, a 24% decrease in quantity and a 10% decrease in value compared with those of 1997 (table 4). Imports totaled 19,600 kilograms gross weight valued at $138 million, a 16% increase in quantity and a 5% increase in value compared with those of 1997 (table 5).

In 1998, U.S. exports of rare earths decreased in all four trade categories, as listed in table 4. The United States exported 603,000 kilograms of rare-earth metals, a 26% decrease compared with that of 1997, valued at more than $3.7 million. Principal destinations, in descending order of quantity, were Japan, China, the United Kingdom, and Taiwan. Exports of cerium compounds, primarily for glass polishing and automotive catalytic converters, decreased by

21%, to 4,640,000 kilograms valued at $39.6 million. Major destinations, in descending order of quantity, were the Republic of Korea, Germany, United Kingdom, and Japan.

Exports of inorganic and organic rare-earth compounds decreased to 1,630,000 kilograms in 1998 from 1,660,000 kilograms in 1997, and the value of the shipments decreased by almost 6% to $16.6 million. Shipments, in descending order of quantity, were to Japan, Colombia, Canada, and China.

U.S. exports of ferrocerium and other pyrophoric alloys decreased to 2,760,000 kilograms valued at $10.6 million from 4,310,000 kilograms valued at $16.9 million in 1997. Principal destinations, in descending order of quantity, were Canada, El Salvador, Saudi Arabia, and Japan.

The approximate distribution of imports based on analysis of Journal of Commerce data was as follows: glass polishing and ceramics, 34%; automotive catalytic converters, 33%; metallurgical additives and alloys, 13%; permanent magnets, 8%; petroleum refining catalysts, 6%; phosphors for lighting, televisions, computer monitors, radar, and X-ray intensifying film, 4%; and miscellaneous, 2%.

In 1998, U.S. imports of compounds and alloys increased for five out of seven categories, as listed in table 5. China and France dominated the import market, especially for mixed and individual rare-earth compounds.

Imports of cerium compounds totaled 7,380,000 kilograms valued at $22.8 million. After a major decline in imports in 1997, the quantity of cerium compounds imported increased by 172%, the result of increased demand for automotive exhaust catalysts and decreased production from the major domestic producer. China was the major supplier for the fourth year in a row.

Imports of yttrium compounds containing between 19 and 85 weight-percent oxide equivalent (yttrium concentrate) increased by 122% in 1998. China was the leading supplier of yttrium compounds, followed by Hong Kong and Japan.

Imports of individual rare-earth compounds, traditionally the major share of rare-earth imports, declined by 47% compared with those of 1997. Rare-earth compound imports fell to 4,960,000 kilograms valued at $69.1 million. The major sources of individual rare-earth compounds were China, France, and Japan. Imports of mixtures of rare-earth oxides, other than cerium oxide, increased by almost 170% to 2,530,000 kilograms valued at $19.0 million. Principal sources, in descending order of quantity, were China, Thailand, and Japan. Imports of rare-earth metals and alloys into the United States totaled 794,000 kilograms in 1998, an 80% increase compared with those of 1997, valued at $14.0 million. The principal rare-earth metal sources, in descending order of quantity, were Japan and China. Metal imports increased as demand for mischmetal for steel additives and specialty mischmetals for rechargeable batteries increased.

In 1998, imports of rare-earth chlorides increased by 15.7% to 3,650,000 kilograms valued at $8.86 million. Supplies of rare-earth chloride, in descending order of quantity, came from China, India, the United Kingdom, and Japan. Rare-earth chloride was used mainly as feed material for manufacturing fluid cracking catalysts. Imports of ferrocerium and pyrophoric alloys decreased by 3.6% to 131,000 kilograms valued at $1.87 million. Principal suppliers, in descending order, were France, Austria, and Brazil.

World Review

China, France, and India were major import sources of rare-earth chlorides, nitrates, and other concentrates and compounds (table 5). Thorium-free intermediate compounds as refinery feed were still in demand because industrial consumers expressed concerns with radioactive thorium’s potential liabilities, the costs of complying with environmental monitoring and regulations, and costs at approved waste disposal sites. Demand for rare earths decreased slightly in the United States as the rate of economic growth slowed. In 1998, estimated world production of rare earths increased slightly to 70,200 tons of REO (table 6). Production of monazite concentrate was estimated at 7,250 tons (table 7).

World reserves of rare earths were estimated by the USGS to be 100 million tons of contained REO in 1998. China, with 43%, had the largest share of those world reserves.

Australia.—Although it did not produce rare-earth minerals in 1998, Australia remained one of the world’s major potential sources of rare-earth elements from its heavy-mineral sands and rare-earth laterite deposits. Monazite is a constituent in essentially all of Australia’s heavy-mineral sands deposits. It is normally recovered and separated during processing but was returned to tailings because of a lack of demand. In 1998, major producers of heavy-mineral sand concentrates were RGC Ltd. (RGC), Westralian Sands Ltd. (WSL), Tiwest Joint Venture, Cable Sands Ltd., and Consolidated Rutile Ltd. (CRL).

RGC and WSL merged their heavy-mineral sands operations in December 1998. The newly merged corporation’s U.S. operations will reportedly be known as Iluka Resources Inc. RGC (USA), a subsidiary of RGC, which completed construction of its new mine in October 1997, began production of heavy-mineral sands at Stony Creek, VA, in 1998 (Chris Wyatt, RGC (USA), oral commun., 1998).

RGC was exploring extensively for heavy-mineral sands in Australia. The company reportedly had 55,000 square kilometers of exploration rights in the Murray Basin, which covers parts of New South Wales, South Australia, and Victoria. The company was conducting a prefeasibility study for a mine at either Kulwin or Woornack, Victoria (Industrial Minerals, 1998d).

RGC’s announced exploration work at its Eneabba deposit in Western Australia had identified additional reserves. These reserves will extend the life of the Eneabba Mine to 12 years. During 1998, the dry mill was moved to a site 10 kilometers south of its former location. The dredge was expected to be moved at yearend 1999 from the Eneabba West location to the extended reserves at Pharaoh’s Flat on the northern edge of the Eneabba deposit (Industrial Minerals, 1998e).

WSL announced the closure of its Yoganup North Mine in

Western Australia in October 1998. Yoganup's processing plant was transferred to WSL's North Capel Mine. Mineral sands production at the North Capel Mine increased in 1998. The increase in production was expected, the result of a February 1998 startup of a new plant at the North Capel Mine (Mineral Sands Report, 1999d).

In 1998, CRL increased production from its Gordon and Ibis-Alpha Mines. Both CRL dredges operated at full capacity during the year. In 1997, CRL upgraded and moved one dredge and the floating concentrator from its exhausted Bayside deposit to its Ibis-Alpha heavy-mineral deposit on North Stradbroke Island, Queensland. CRL planned to move the other dredge from its Gordon mine site to its Yarraman ore body also on North Stradbroke Island in 1999. The Yarraman deposit, which was expected to begin production by yearend 1998, had an expected mine life of 13.5 years at a 3,000-metric-ton-per-hour mining rate (Industrial Minerals, 1998b). As a result of CRL's move, mineral sands production was expected to decrease in 1999 (Mineral Sands Report, 1999a).

In 1998, CSL started production from its new mine at Sandalwood, Western Australia, and continued operations at its two other mines in Western Australia at Jangardup, its largest operation, and at Yarloop, 55 kilometers northeast of Bunbury (Mineral Sands Report, 1999b).

In May 1998, The Broken Hill Proprietary Company Limited (BHP) declared force majeure at its mine in Beenup, Western Australia. BHP noted that the mine, which began production in January 1996, was having difficulty producing at capacity. Problems have included excessive wear on the dredge and concentrator and tailings consolidation problems (The Broken Hill Proprietary Company Limited, May 26, 1998, Titanium minerals project update, press release, accessed January 12, 1999, at URL http://www.bhp.com.au/press/ bhp_press/data/19980526a.html). The mine was expected to produce up to 3,500 tons per hour of ore. Shipments of heavy-mineral concentrates began in 1997 (The Broken Hill Proprietary Company Limited, 1997). The Beenup Mine reportedly operated significantly below capacity levels in 1997 as a result of startup problems (Minerals Sands Report, 1998).

Tiwest Joint Venture, an Australian collaboration of Kerr-McGee Corp. (USA) and Minproc Holdings, of Australia, operated a heavy-mineral sands mine at Cooljarloo, Western Australia. Reserves at the deposit were 177 million metric tons of sands grading 3.7% heavy minerals. In 1998, production was 418,000 tons of heavy-mineral concentrates (Mineral Sands Report, 1999c).

BHP Titanium Minerals Pty. Ltd. (formerly Mineral Deposits Pty. Ltd.) sold its Viney Creek and Fullerton, New South Wales, heavy-mineral sands operations to Nimbus Resources NL in October 1998 (Mineral Sands Report, 1999b). As part of the acquisition, Nimbus acquired the rights to the established corporate name "Mineral Deposits Limited" (MDL). Subsequently, Nimbus and its associated mining group, Dreadnought Mining NL joined under the acquired corporate name MDL (Mineral Deposits Limited, 1998, Welcome to Mineral Deposits Limited, accessed May 4, 1999, at URL http://www.mineraldeposits.com.au/index.html). Wet mill concentrate from the two mines was trucked to the dry mill at Hawks Nest, New South Wales, for separation.

RZM Pty. Ltd. operated a heavy-mineral sands mine near Newcastle and a dry mill at Tomago, New South Wales. RZM and Western Metals Limited (formerly Aberfoyle Limited) have reportedly identified a high-grade rutile and zircon mineral sands deposit at Wemen, New South Wales, and were proceeding with development (Western Metals Limited, September 19, 1998, Western Metals, accessed May 4, 1999, at URL http://www.reflections.com.au/MiningandExploration/Companies/Archives.html).

Austria.—Treibacher Industrie AG celebrated the 100th anniversary of its rare-earth company. Founded in 1898 as Treibacker Chemische Werke AG by Carl Auer von Welsbach, the company and founder were responsible for the first major commercialization of rare-earth products (in incandescent lamp mantles and lighter flints). In 1998, Treibacher continued to produce rare-earth products, including lighter flints, mischmetal, hydrogen storage alloys, vacuum alloys, mixed rare-earth compounds for petroleum fluid cracking catalysts, ceramic materials, additives for glass and ceramics, and specialty pure metals and alloys (Rare-earth Information Center News, 1998d).

Canada.—Strider Resources Limited announced that its Eden Lake rare element property was available for option. Located at Eden Lake, 24 kilometers northwest of Leaf Rapids, Manitoba, the undrilled deposit contains surface mineralization in the rare-earth mineral britholite. Outcrop sampling of the Eden Lake syenite intrusive complex showed 8% britholite from a 32-kilogram sample. Biogeochemical sampling indicated an extension of the mineralization 1 kilometer to the south (Manitoba Energy and Mines, June 13, 1997, Eden Lake rare-element property, accessed January 12, 1999, at URL http://www.gov.mb.ca/em/minerals/properties/strider.html #01).

Highwood Resources Ltd. conducted an exploration program of its Thor Lake beryllium-yttrium-lanthanide property in the Northwest Territories. Discovered in 1976, the alkaline complex is located 100 kilometers southeast of Yellowknife and is covered by five mineral leases totaling 4,250 hectares. Rock types in the Blachford Lake alkaline complex range from gabbros, anorthosites, and syenites to quartz syenites and granites. Permits to obtain a large bulk sample from the Thor Lake property and to build a milling facility in the town of Hay River were submitted (Highwood Resources Ltd., [undated], Thor Lake property, accessed July 28, 1999, at URL http:// highwood-resources.com/thorlake.htm).

YBM Magnex International, Inc. (YBM), a Canadian company with subsidiaries in Hungary, the United Kingdom, and the United States, was the target of an international investigation for alleged money laundering and ties to organized crime in Europe. Crumax, YBM's rare-earth subsidiary in the United States, produced rare-earth permanent magnets. On May 13, 1998, a cease trading order issued by the Ontario Securities Commission to YBM coincided with a raid by several Federal U.S. law enforcement agencies on YBM's corporate offices in Newton, PA. On December 8, 1998, YBM entered receivership with Ernest and Young ALL Inc., which had been announced as the receiver and manager of all its assets and operations (Rare-earth Information Center Insight, 1998c). The company was delisted from the Toronto Stock Exchange on December 15, 1998.

China.—Advanced Material Resources Ltd. of Canada announced it had purchased Japanese technology and equipment from Nippon Yttrium Corp. for its China joint-venture processing plant at Jiangyin, Jiangsu Province. The new equipment will boost yttrium oxide capacity by 120 to 150 tons per year. Total yttrium oxide capacity will be about 500 tons. Rare-earth oxide output from the plant in 1997 was 807 tons (Industrial Minerals, 1998a).

Rhodia signed an agreement with officials of the Baotou Rare Earth Development Zone, Inner Mongolia, to construct a production facility to produce rare-earth alloys and metal hydride powder for rechargeable batteries. The production stream was to be built at Baotou, and will initially supply only battery markets within China (Industrial Minerals, 1998c).

Magnequench announced two expansions in its rare-earth permanent magnet business. The first was the acquisition of Xinbao, a neodymium alloy production facility. The second was Magnequench's plan to build a neodymium-iron-boron powder magnet plant near the municipality and port of Tianjin in northeastern China (Maqnequench International, Inc., September 12, 1998, New Technology Center, accessed September 15, 1998 at URL http://www.mqii.com/whoweare/narch91298a.html).

***France.*—**Rhône-Poulenc, which had previously renamed its specialty chemicals division Rhodia, planned to create a separate unit for its rare-earth products. The new unit, Rhodia Rare Earths, part of Rhodia's services and specialties division, moved its corporate headquarters from Paris to La Rochelle, the site of its rare-earth separation plant (Industrial Minerals, 1998f). Rhodia Rare Earths has about 500 employees at La Rochelle.

Japan.—Mitsui Mining & Smelting Company, Ltd., announced that it would build a 1,500-square-meter plant to produce hydrogen storage nickel-metal hydride batteries for the automotive industry. Increased demand for electric and hybrid electric-gas vehicles has increased demand for rare-earth-containing nickel-metal hydride batteries (Rare-earth Information Center News, 1998b). Toyota Motor's Prius hybrid electric-gas vehicle, which uses 15 kilograms of rare-earth magnets per vehicle, also contains about 140 kilograms of rechargeable batteries (Linda L. Gaines, Argonne National Laboratory, oral commun., 1998).

Kenya.—Tiomin Resources Inc. (Canada) completed its prefeasibility assessment of its Kwale heavy-mineral sands deposit. Resources of 200 million tons of ore were estimated to provide a 15-year mine life. Tiomin acquired an 80% interest in the licensed mineral rights, and partner Pangea Goldfields Inc. retained the remaining 20%. Tiomin has arranged financing for the project with Aur Resources Inc. and was expected to complete a bankable feasibility report during 1999 (Tiomin Resources Inc., December 29, 1998, Tiomin arranges funding with Aur Resources to proceed to feasibility at Kwale project, news release, accessed January 12, 1999, at URL http://www.tiomin.com/s/NewsReleases.asp?ReportID=3032).

South Africa.—Iscor Mining, a subsidiary of Iscor Limited, has deferred development of the Iscor Heavy Minerals project in KwaZulu-Natal Province until the last half of 1999. The primary reasons for the delay were the high interest rates in South Africa and global economic uncertainty (Iscor Mining, January 10, 1998, Iscor Heavy minerals, information release, accessed June 3, 1999, at URL http://www.iscorltd.co.za/ihm/ press_articles/98100101.htm).

Current Research and Technology

Researchers at Symyx Technologies, Inc., in Santa Clara, CA, discovered a new rare-earth phosphor by using a combinatorial method to prepare 25,000 luminescent samples. The new blue-white phosphor Sr_2CeO_4 is an unusual type with a one-dimensional chain structure. This new class of luminescent material may have future use in flat-panel displays, fluorescent lighting, television and computer CRT monitors, and temperature sensing (Rare-earth Information Center News, 1998c).

An optical pressure gauge was developed for diamond anvil cells using rare earths by researchers at the University of Paris, France. Pressure measurement in diamond anvils have been traditionally made by the shift in fluorescence line of ruby. Improved measurement and calibration of high-pressure within the diamond anvil has been obtained by using $SrB_4O_7{:}Sm^{2+}$. The compound emits in the same spectral range as the ruby line but with higher intensity, fluoresces as a singlet Sm^{2+} line, and is stable to higher pressures. The samarium compound is usable above 100 gigapascals and to temperatures of 800° K (Rare-earth Information Center Insight, 1998a).

Scientists are studying the application of the green rare-earth phosphor $SrGa_2S_4{:}Eu^{2+}$ for field-emission arrays to produce displays that are lighter weight, take up less space, and use less electricity than CRT's. Compared with the standard green CRT phosphor ZnS:Cu,Al, the rare-earth phosphor $SrGa_2S_4{:}Eu^{2+}$ displayed the highest luminance for a given current density. In a field-emission display (FED), each pixel operates independently and creates an electron stream by field emission compared with a CRT screen, which creates an electron stream by thermal emission. With a pixel address time of 10 nanoseconds, a CRT screen must be scanned or rastered continuously to refresh each pixel in the image, thus using more energy. A FED transfers its field emission energy approximately 60 times during its 30-microsecond pixel address time, allowing a pixel that does not need to change color to remain activated until that part of the image changes or the phosphor needs excitation (Rare-earth Information Center Insight, 1998b).

Energen, Inc., of Massachusetts received a National Aeronautics and Space Administration contract to develop rare-earth actuators for the Next Generation Space Telescope (NGST). Energen will engineer the dysprosium-terbium-iron magnetostrictive alloys for the NGST to allow ground-based control of the reflective surface and optical focusing. The use of the rare-earth alloy will allow precision positioning of the telescope based on the alloy's ability to expand and contract accurately when subjected to a magnet field. The NGST was expected to have 6 to 12 times the surface area of the Hubble Space Telescope (Rare-earth Information Center News, 1998a).

Outlook

Global use of rare earths, especially in automotive pollution catalysts, permanent magnets, and rechargeable batteries, is expected to continue to increase as demand for automobiles, electronics, computers, and portable equipment grows. Rare-earth markets are expected to require greater amounts of higher purity mixed and separated products. Strong demand is expected to continue into the next decade for cerium and neodymium for use in automotive catalytic converters and permanent magnets. Future growth is forecast for rare earths in magnetic refrigeration, rechargeable nickel hydride batteries, fiber optics, and medical applications, including magnetic resonance imaging (MRI) contrast agents and dental and surgical lasers.

World reserves are sufficient to meet forecast world demand well into the 21st century. Several world class rare-earth deposits in Australia and China have yet to be developed because world demand is currently (1998) being satisfied by existing production (Singer, 1995). World resources should be adequate to fulfill demand for the foreseeable future.

Domestic companies have shifted away from using naturally occurring radioactive rare-earth ores. This trend has had a negative impact on monazite-producing mineral sands operations worldwide. Future long-term demand for monazite, however, is expected to increase because of its abundant supply and recovery as a low-cost byproduct. The cost and space to dispose of radioactive waste products in the United States are expected to continue to increase, severely limiting domestic use of low-cost monazite and other thorium-bearing rare-earth ores.

World markets are expected to continue to be very competitive based on lower wages and fewer environmental and permitting requirements. China is expected to remain the world's principal rare-earth supplier. The future economic restructuring of Asia and Eastern Europe will create large potential markets for new sources and consumers.

The long-term outlook is for an increasingly competitive and diverse group of rare-earth suppliers. As research and technology continue to advance the knowledge of rare earths and their interactions with other elements, the economic base of the rare-earth industry is expected to continue to grow. New applications are expected to continue to be discovered and developed.

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TABLE 1
SALIENT U.S. RARE EARTH STATISTICS 1/

(Metric tons of rare-earth oxides (REO) unless otherwise specified)

	1994	1995	1996	1997	1998
Production of rare-earth concentrates 2/	20,700	22,200	20,400	10,000 r/ e/	5,000 e/
Exports:					
Cerium compounds	4,460	5,120	6,100	5,890	4,640
Rare-earth metals, scandium, and yttrium	329	444	250	991	724
Ores and concentrates	--	--	2	--	--
Rare-earth compounds, organic or inorganic	2,420	1,550	2,210	1,660	1,630
Ferrocerium and pyrophoric alloys	3,020	3,470	4,410	3,830	2,460
Imports for consumption: e/					
Monazite	--	22	56	11	--
Cerium compounds	--	--	3,180	1,820 r/	4,940
Ferrocerium and pyrophoric alloys	69	78	107	121	117
Metals, alloys, oxides, and other compounds	7,840	14,100	14,000 r/	10,000	8,950
Stocks, producers and processors, yearend	NA	NA	NA	NA	NA
Consumption, apparent	17,800 e/	NA	NA	NA	NA
Prices, yearend, per kilogram:					
Bastnasite concentrate, REO basis	$2.87	$2.87	$2.87	$2.87 e/	$2.87 e/
Monazite concentrate, REO basis	$0.46	$0.44	$0.48	$0.73	$0.73
Mischmetal, metal basis	$12.68	$9.50	$8.75 3/	$8.45 3/	$16.00 3/
Employment, mine and mill 4/	NA	NA	NA	NA	NA
Net import reliance as a percentage of apparent consumption 5/	(6/)	(7/)	(7/)	(7/)	(7/)

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to three significant digits, except prices.

2/ Comprises only the rare earths derived from bastnasite as obtained from Molycorp, Inc., company representative.

3/ Source: Elements--Rare Earths, Specialty Metals and Applied Technology,TradeTech, Denver, CO.

4/ Employment at a rare-earth mine in California and at a mineral sands operation in Florida. The Florida mine produced monazite as a byproduct, and employees were not assigned to specific commodities. The mineral sands operation in Florida ceased recovery of monazite at the end of 1994.

5/ Imports minus exports plus adjustments for Government and industry stock changes.

6/ Net exporter.

7/ Net importer.

TABLE 2
RARE EARTH CONTENTS OF MAJOR AND POTENTIAL SOURCE MINERALS 1/

(Percent of total rare-earth oxide)

Rare earth	Bastnasite, Mountain Pass, CA, USA 2/	Bastnasite, Bayan Obo, Inner Mongolia, China 3/	Monazite, North Capel, Western Australia 4/	Monazite, North Stradbroke Island, Queensland, Australia 5/	Monazite, Green Cove Springs, Fl, USA 6/	Monazite, Nangang, Guangdong, China 7/
Yttrium	0.10	trace	2.40	2.50	3.20	2.40
Lanthanum	33.20	23.00	23.90	21.50	17.50	23.00
Cerium	49.10	50.00	46.00	45.80	43.70	42.70
Praseodymium	4.34	6.20	5.00	5.30	5.00	4.10
Neodymium	12.00	18.50	17.40	18.60	17.50	17.00
Samarium	.8000	.8000	2.53	3.10	4.90	3.00
Europium	.1000	.2000	.0530	.8000	.1600	.1000
Gadolinium	.2000 r/	.7000	1.49	1.80	6.60	2.00
Terbium	trace	.1000	.0350	.3000	2600	.7000
Dysprosium	trace	.1000	.7000	.6000	.9000	.8000
Holmium	trace	trace	.0530	.1000	.1100	.1200 r/
Erbium	trace	trace	.2000	.2000	trace	.3000
Thulium	trace	trace	trace	trace	trace	trace
Ytterbium	trace	trace	.1000	.1000	.2100	2.40
Lutetium	trace	trace	trace	.0100	trace	.1400 r/
Total	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000

Rare earth	Monazite, East coast, Brazil 8/	Monazite, Mount Weild, Australia 9/	Xenotime, Lahat, Perak,Malaysia 2/	Xenotime, southeast, Guangdong, China 10/	Rare earth laterite Xunwu, Jiangxi Province, China 11/	Rare earth laterite Longnan, Jiangxi Province, China 11/
Yttrium	1.40	trace	61.00	59.30	8.00	65.00
Lanthanum	24.00	26.00	1.24 r/	1.20	43.40	1.82
Cerium	47.00	51.00	3.13 r/	3.00	2.40	.4000
Praseodymium	4.50	4.00	.5000	.6000	9.00	.7000
Neodymium	18.50	15.00	1.60	3.50	31.70	3.00
Samarium	3.00	1.80	1.10	2.20	3.90	2.80
Europium	.1000	.4000	trace	.2000	.5000	0.10
Gadolinium	1.00	1.00	3.50	5.00	3.00	6.90
Terbium	.1000	.1000	.9000	1.20	trace	1.30
Dysprosium	.4000	.2000	8.30	9.10	trace	6.70
Holmium	trace	.1000	2.00	2.60	trace	1.60
Erbium	.1000	.2000	6.40	5.60	trace	4.90
Thulium	trace	trace	1.10	1.30	trace	.7000
Ytterbium	.0200 r/	.1000	6.80	6.00	.3000	2.50
Lutetium	not determined	trace	1.00	1.80	.1000	.4000
Total	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000

r/ Revised.
1/ Data are rounded to three significant digits: may not add to totals shown.
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TABLE 3
RHODIA RARE EARTH OXIDE PRICES IN 1998

Product (oxide)	Percentage purity	Standard package quantity (kilograms)	Price per kilogram
Cerium	95.00	25	$19.00
Cerium	99.50	25	23.00
Dysprosium	95.00	20	65.00
Erbium	96.00	20	150.00
Europium	99.99	10	700.00
Gadolinium	99.99	50	115.00
Holmium	99.90	10	485.00
Lanthanum	99.99	25	23.00
Lutetium	99.99	2	4,500.00
Neodymium	95.00	20	22.00
Praseodymium	96.00	20	32.00
Samarium	96.00	25	75.00
Terbium	99.90	5	685.00
Thulium	99.90	5	3,600.00
Ytterbium	99.00	10	230.00
Yttrium	99.99	50	85.00

TABLE 4
U.S. EXPORTS OF RARE EARTHS, BY COUNTRY 1/

Category and country 2/	1997		1998	
	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Cerium compounds: (2846.10.0000)				
Australia	37,800	$332,000	13,300	$123,000
Belgium	19,300	167,000	73,400	413,000
Brazil	43,900	680,000	92,000	565,000
Canada	405,000	4,140,000	179,000	1,580,000
France	49,100	160,000	150,000	925,000
Germany	759,000	9,380,000	747,000	14,600,000
Hong Kong	82,800	722,000	57,100	430,000
India	406,000	653,000	5,740	178,000
Japan	148,000	1,560,000	326,000	3,770,000
Korea, Republic of	2,010,000	11,000,000	1,250,000	5,520,000
Malaysia	593,000	3,540,000	280,000	1,750,000
Mexico	105,000	736,000	160,000	1,600,000
Netherlands	18,600	56,500	147,000	443,000
Singapore	521,000	1,810,000	18,800	19,000
South Africa	9,290	183,000	103,000	3,520,000
Taiwan	348,000	1,440,000	205,000	1,030,000
United Kingdom	151,000	976,000	595,000	2,120,000
Other	186,000 r/	894,000 r/	234,000	1,040,000
Total	5,890,000	38,400,000	4,640,000	39,600,000

See footnotes at end of table.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY 1/

Category and country 2/	1997 Gross weight (kilograms)	1997 Value	1998 Gross weight (kilograms)	1998 Value
Cerium compounds, including oxides, hydroxides, nitrates, sulfate chlorides, oxalates: (2846.10.0000)				
Austria	35,500	$425,000	31,400	$358,000
China	2,340,000	12,200,000	7,000,000	16,100,000
France	191,000	4,280,000	287,000	4,850,000
Japan	57,900	1,120,000	43,700	1,270,000
Spain	51,000	375,000	--	--
Other	39,200 r/	358,000 r/	19,000	259,000
Total	2,710,000	18,800,000	7,380,000	22,800,000
Yttrium compounds content by weight greater than 19% but less than 85% oxide equivalent: (2846.90.4000)				
China	23,500	487,000	75,300	1,580,000
France	18,300	765,000	4,960	272,000
Germany	25	11,400	2,730	48,700
Hong Kong	--	--	17,000	232,000
Japan	181	16,400	7,150	133,000
Norway	576	101,000	--	--
United Kingdom	4,410	115,000	42	178,000
Other	185 r/	12,300 r/	81	16,500
Total	48,400	1,550,000	107,000	2,460,000
Rare-earth compounds, including oxides, hydroxides, nitrates, other compounds except chlorides: (2846.90.8000)				
Austria	--	--	7,690	309,000
China	7,010,000	29,800,000	3,160,000	20,100,000
Estonia	152,000	307,000	48,900	80,400
France	1,860,000	15,500,000	1,150,000	15,200,000
Germany	6,810	138,000	19,900	321,000
Hong Kong	8,510	234,000	17,000	247,000
Hungary	--	--	18,400	217,000
Japan	262,000	10,000,000	401,000	13,100,000
Malaysia	--	--	2,210	252,000
Norway	3,120	6,430,000	11,400	11,700,000
Russia	33,000	643,000	3,020	189,000
Spain	15,000	264,000	--	--
Taiwan	422	73,900	34,100	543,000
United Kingdom	65,500	5,560,000	53,500	6,730,000
Other	16,500 r/	41,400 r/	35,600	122,000
Total	9,420,000	69,000,000	4,960,000	69,100,000
Mixtures of rare-earth oxides except cerium oxide: (2846.90.2010)				
Austria	21,100	1,350,000	19,100	1,140,000
China	834,000	9,680,000	2,370,000	9,080,000
France	7,500	378,000	18,200	769,000
Germany	3,140	181,000	10,200	2,080,000
Japan	32,400	5,250,000	37,800	5,510,000
Korea, Republic of	34,000	36,400	--	--
Russia	1,150	377,000	--	--
Thailand	--	--	58,300	180,000
United Kingdom	3,520	320,000	350	5,420
Other	954 r/	82,500 r/	15,000	202,000
Total	938,000	17,700,000	2,530,000	19,000,000
Rare-earth metals, whether intermixed or alloyed: (2805.30.0000)				
China	337,000	7,420,000	344,000	4,530,000
Hong Kong	20,700	149,000	73	3,370
Japan	67,900	1,530,000	439,000	9,030,000
Russia	5,250	338,000	2,490	195,000
United Kingdom	7,230	362,000	6,580	136,000
Other	2,510 r/	212,000 r/	2,320	136,000
Total	441,000	10,000,000	794,000	14,000,000

See footnotes at end of table.

TABLE 5--Continued
U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY 1/

Category and country 2/	1997 Gross weight (kilograms)	1997 Value	1998 Gross weight (kilograms)	1998 Value
Mixtures of rare-earth chlorides, except cerium chloride: (2846.90.2050)				
China	1,730,000	5,540,000	3,050,000	5,470,000
Estonia	26,400	416,000	--	--
France	12,000	755,000	14,500	774,000
India	1,290,000	1,900,000	479,000	602,000
Japan	59,400	2,670,000	38,600	1,180,000
Taiwan	540	19,300	20,100	318,000
United Kingdom	27,000	642,000	42,100	264,000
Other	15,000 r/	270,000 r/	6,120	251,000
Total	3,160,000	12,200,000	3,650,000	8,860,000
Ferrocerium and other pyrophoric alloys: (3606.90.3000)				
Austria	7,090	154,000	6,670	154,000
Brazil	7,500	150,000	4,500	86,500
France	119,000	1,720,000	111,000	1,500,000
Other	3,140	47,200	8,850	138,000
Total	136,000	2,070,000	131,000	1,870,000

r/ Revised

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ U.S. and International trade commission of harmonized code tariff category number.

Source: Bureau of the Census.

TABLE 6
RARE EARTHS: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of rare earth oxide equivalent)

Country 3/	1994	1995	1996	1997	1998 e/
Australia e/	--	110	--	--	--
Brazil	256	103	--	--	--
China e/	30,700 r/	48,000 r/	55,000 r/	53,000 r/	60,000
India e/	2,500	2,700	2,700	2,700	2,700
Malaysia	234	448	340	378 r/	350
South Africa	72	--	-- e/	-- e/	--
Sri Lanka e/	120	120	120	120	120
Thailand	57	--	--	12 r/	--
U.S.S.R. e/ 5/	2,000	2,000	2,000	2,000	2,000
United States 6/	20,700	22,200	20,400	10,000 r/ e/	5,000
Total	56,600 r/	75,700 r/	80,600 r/	68,200 r/	70,200

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data have been rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through May 27, 1999.

3/ In addition to the countries listed, rare-earth minerals are believed to be produced in Indonesia, Mozambique, North Korea, and Vietnam, but information is inadequate to formulate reliable estimates.

4/ Formerly Zaire.

5/ Dissolved in December 1991; however, information is inadequate to formulate reliable estimates for individual producing countries, including Kazakhstan, Krygystan, Russia, and Ukraine.

6/ Comprises only the rare earths derived from bastnasite as reported from company sources.

TABLE 7
MONAZITE CONCENTRATE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country 3/	1994	1995	1996	1997	1998 e/
Australia e/	--	200 r/	--	--	--
Brazil e/	1,400	1,400	1,400	1,400	1,400
China	NA	NA	NA	NA	NA
India e/	4,600	5,000	5,000	5,000	5,000
Malaysia	426 r/	822 r/	618	688 r/	650
South Africa e/ 4/	131	--	--	--	--
Sri Lanka e/	200	200	200	200	200
Thailand	57	--	--	12 r/	--
United States	W	--	--	--	-- 5/
Total	6,810	7,620 r/	7,220	7,300 r/	7,250

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; excluded from "Total."
1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through May 27, 1999.
3/ In addition to the countries listed, Indonesia, North Korea, the Republic of Korea, Nigeria, and the former U.S.S.R. may produce monazite; available general information is inadequate for formulation of reliable estimates of output levels.
4/ Monazite occurs in association with titanium sands mining but is not necessarily recovered.
5/ Reported figure.